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(54) **Photomultiplier**

Photovervielfacher

Photomultiplicateur

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(56) References cited:
US-A- 2 868 994
US-A- 4 431 943
US-A- 4 855 642

- **PATENT ABSTRACTS OF JAPAN vol. 15, no. 70 (E-1035) 19 February 1991 & JP-A-02 291 654**

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Description

Background of the Invention

Field of the Invention

This invention relates to a photomultiplier for detecting very feeble light by cascade-multiplying photoelectrons by using a number of dynodes, and specifically to a photomultiplier having an electrode positioned so as to act on secondary electrons emitted from a first dynode to a second dynode, and positioned adjacent a third dynode of a subsequent stage to said first and second dynodes.

Related Background Art

A structure of this type of photomultiplier is exemplified by one described in Japanese Patent Laid-Open Publication No. 291654/1990 which is shown in Fig. 1.

The photomultiplier of Fig.1 is of the so-called head-on type. In a glass tube 101 there are provided a photocathode 103 on an inside wall thereof, a focusing electrode 102, dynodes 104 - 113, and anodes 114. The voltage distribution of 350 - 1200 V which are increased toward the anodes 114 are applied to the dynodes 104 - 113. A pole electrode 115 is disposed between the first dynode 104 and the second dynode 105 for accelerating secondary electrons generated by the first dynode 104. A voltage sufficiently higher than that applied to the first dynode 104 (e.g., the same voltage as that applied to the fourth dynode 107) is applied to the pole electrode 115.

When light is incident on a photocathode 103, photoelectrons are liberated. These photoelectrons are gathered to the focusing electrode 102 and sent to the first dynode 104. In the first dynode 104, secondary electrons are liberated by these photoelectrons and sent to the second dynode 105. The thus-generated secondary electrons at each of the following dynodes 105 ~ 113 are sent sequentially to its next dynode to be multiplied (cascade-multiplied), and multiplied photoelectrons are taken out finally at the anodes 114.

In the photoelectric multiplier of FIG. 1, a pole electrode 115 is disposed behind the third dynode 106, and the former 115 has a higher potential than the latter. Because of the presence of the pole electrode 115 at such position, which has a higher potential than the third dynode 106, an equipotential line E there is bulged toward the first dynode 104. Because of such distribution of the equipotential line E, the secondary electrons emitted from the first dynode 104 are more accelerated when they transit toward the second dynode 105. Consequently an electron transit time of the emitted secondary electrons as a whole is shortened, whereby a spread of the electron transit time is relatively decreased.

In the acceleration of the secondary electrons by the above-described pole electrode 115, secondary electrons generated near the pole electrode 115 behind the dynode 104 are more accelerated. But secondary electrons emitted remote from the pole electrode 115 are less accelerated because their orbits are spaced from the pole electrode 115. Consequently spreads (TTS's) of electron transit times cannot be sufficiently suppressed. As high-speed very feeble light pulse measurement, such as fluorescence lifetime measurement, time-resolved spectroscopy, etc., has been recently improved, photomultipliers having better transient response characteristics are needed.

The documents US-A-4 431 943 and US-A-2 868 994 each disclose a cascade-multiplying photomultiplier having additional accelerating electrodes.

According to one aspect of the present invention, there is provided a photomultiplier of the above type, characterised in that said electrode is a decelerating electrode connected to a source of a lower potential than that of said third dynode, so as to reduce the spread in the transit times of the electrons between said first and second dynodes.

According to another aspect of the present invention, there is provided a photomultiplier of the above type, characterised in that said electrode is a decelerating electrode electrically connected to said second dynode, for reducing the spread in the transit times of the electrode between said first and second dynodes.

According to another aspect of the present invention, there is provided a method of operating a photomultiplier of the above type, said method being characterised by applying to said electrode a lower potential than that of said third dynode, so as to reduce the spread in the transit times of the electrons between said first and second dynodes.

An advantage of the present invention is that it provides a photomultiplier which can decrease spreads of electron transit times in cascade-photomultiplication of electrons, and is suitable to measure high-speed light pulse in fields of fluorescence lifetime measurement and high-energy physics.

Thus, a photomultiplier according to the present invention can sufficiently suppress spreads of electron transit times, and has good transient response characteristics.

A photomultiplier according to this invention for receiving incident light on a photocathode and cascade-multiplying by secondary electronic effect of a plurality of dynodes electrons emitted from the photocathode for the detection of the incident light may comprise a slowing-down electrode for decelerating those of secondary electrons emitted from a dynode on the first stage to a dynode on the second stage which have a higher speed.

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Generally in a photomultiplier, sequentially increasing voltages are applied to dynodes at respective stages of the cascade multiplication. Voltages to the dynodes at the respective stages, and a geometrical arrangement of the dynodes make up electric potentials. The potentials influence a speed of the secondary electrons and cause differences in a time in which the secondary electrons reach a next dynode.

In a photomultiplier according to this invention, a slowing-down electrode may be provided so that those of secondary electrons emitted from the dynode on the first stage to the dynode of the second stage which have higher speeds are selectively slowed down, whereby a spread of transit times of the secondary electrons emitted from the dynode on the first stage to the dynode on the second stage is diminished.

The photomultiplier according to this invention may include an accelerating electrode for accelerating those of the secondary electrons emitted from the first stage-dynode to the second stage-dynode which have a lower speed.

The photomultiplier according to this invention may include an orbit correcting electrode for correcting electrode orbits of those of the secondary electrons emitted from the first-stage dynode to the second-stage dynode which pass near the third-stage dynode.

Brief Description of the Drawings

Specific embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic end view of a conventional photomultiplier.

Fig. 2 is an enlarged view of a part of the arranged dynodes.

Fig. 3 is a schematic end view of a photomultiplier in an embodiment of the invention.

Fig. 4A is an enlarged view of a part of an arrangement of dynodes in one embodiment of the present invention.

Fig. 4B is an enlarged view of a part of an arrangement of dynodes in another embodiment of the present invention.

Fig. 4C is an enlarged view of a part of an arrangement of dynodes in another embodiment of the present invention.

Fig. 5A is a graph of electron transit time spreads of the conventional photomultiplier.

Fig. 5B is a graph of electron transit time spreads of the photomultiplier of Fig. 4A.

Fig. 5C is a graph of electron transit time spreads of the photomultiplier of Fig. 4B.

Fig. 5D is a graph of electron transit time spreads of the photomultiplier of Fig. 4C.

Fig. 6 is a perspective view of a part of an arrangement of dynodes in an embodiment of the present invention.

Description of the Preferred Embodiments

Preferred embodiments of the photomultiplier will be explained below with reference to the drawings attached hereto. The same or equivalent members of these embodiments as or to those of the above-described conventional photomultiplier will be briefly explained or not at all. Fig. 3 shows one example of the so-called head-on type photomultiplier.

A photocathode 103 is formed on an inner side of a glass tube 101. On the inner side of glass tube 101, focusing electrodes 120, 121 are held by a holding electrode 122. The focusing electrodes 120, 121 not only converge photoelectrons emitted from the photocathode 103, but also decrease a spread of the electron transit time that the emitted photoelectrons from the photocathode 103 take to arrive at the first dynode 104.

The first dynode 104 is arranged so as to register with the opening of the holding electrode 122 and has a shape in which distances from points on the surface of the first dynode 104 to the second dynode 105 are substantially constant. The dynodes 104 - 113 have geometric structures and arrangements which allow the same to receive the secondary electrons emitted from the dynodes on their preceding stages and converge the received secondary electrons to the dynodes on their following stages to output the electrons. The voltage distribution are applied to the dynodes 104 ~ 113. By this structure the photoelectrons emitted from the photocathode 103 are cascade-multiplied. Anodes 114 are disposed spaced from each other on the side of emission of secondary electrons of the flat dynode 113 on the final stage.

FIG. 4A shows an enlarged view of a part of a plurality of arranged dynodes.

The first dynode 104 and the second dynode 105 are opposed to each other, and the third dynode 106 are so arranged that a part of the third dynode 106 are confronted with electron orbits of secondary electrons emitted from the first dynode 104 to the second dynode 105. A slowing-down electrode 60 is disposed behind the third dynode 106 and is electrically connected to the second dynode 105 by a lead wire 81 (see FIG. 6). Consequently the slowing-down electrode 60 has the same potential as the second dynode 105 and has a potential lower than the neighboring third dynode 106.

Here the function of the slowing-down electrode 60 will be explained.

FIG. 4A shows a distribution of an equipotential line E in a case that the slowing-down electrode 60 is provided. In comparison with a distribution of FIG. 2 with an accelerating electrode 115 provided, a potential formed by the third dynode 106 is less bulged. Consequently the slowing-down electrode 60 functions so that the secondary electrons emitted from a territory A of the first dynode 104 are less accelerated, and a transit time of the secondary electrons

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emitted for the territory A to the second dynode 105 becomes longer.

TABLE 1 shows one example of operational conditions, as of the voltage distribution applied to the photomultiplier.

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TABLE 1

Electrode		Applied Voltage (V)	Potential Difference from Photocathode (V)
Photocathode	(103)	-2250.0	0
Grid 1	(120)	-2079.0	171.0
Acc	(121)	-527.0	1723.0
1st Dynode	(104)	-1448.0	802.0
Slowing-down Electrode	(60)	-1290.0	960.0
Accelerating Electrode	(61)	-922.0	1328.0
2nd Dynode	(105)	-1290.0	960.0
3rd Dynode	(106)	-1053.0	1197.0
4th Dynode	(107)	-922.0	1328.0
5th Dynode	(108)	-790.0	1460.0
6th Dynode	(109)	-658.0	1592.0
7th Dynode	(110)	-527.0	1723.0
8th Dynode	(111)	-395.0	1855.0
9th Dynode	(112)	-263.0	1987.0
10th Dynode	(113)	-132.0	2118.0
Anode Electrode	(114)	0.0	2250.0

An electron orbit 70 of a shorter transit time of those of the secondary electrons emitted from the first dynode 104

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to the second dynode 105, which have a shorter transit time, and an electron orbit 71 of those of the same, which have a longer transit time under the operational conditions of TABLE 1 are shown in FIG. 4A. The electrons having a shorter transit time (the electron orbit 70) take 850 psecs to arrive at the second dynode 105, and the electrons having a longer transit time (the electron orbit 71) take 1100 psecs to arrive at the second dynode 105. The difference between these transit times is 250 psecs. In the prior art, as described in Japanese Patent Laid-Open Publication No. 291654/1990, the transit time is more than 500 psecs. A transit time spread is decreased. FIG. 5 shows distributions of the transit times of the prior art and of the embodiments. In the transit time distribution (FIG. 5B), because of the slowing-down electrode 60, the shorter transit time in the transit time distribution of the prior art (FIG. 5A) is shifted to the longer transit time component, and the longer transit time component is shifted to the shorter time transit component. It is seen that, as a result, the half-value width is narrower.

FIG. 4B shows another embodiment of this invention. The photoelectric multiplier according to this invention includes, in addition to the slowing-down electrode 60, an accelerating electrode 61 disposed further above the slowing-down electrode 60. The accelerating electrode 61 is positioned near electron orbits of the secondary electrons passing remote from the third dynode 106 so as to accelerate the secondary electrons, which are less influenced in this area by a potential of the third dynode 106. Accordingly the accelerating electrode 61 is connected to the fourth dynode 107 by a lead wire 82 and has a higher potential than the third dynode 106 (FIG. 6).

It is seen in FIG. 4B that because of the accelerating electrode 61, the equipotential line E is more bulged toward the first dynode 104 in that area, i.e., the area remote from the third dynode 106. As a result, the secondary electrons passing through the area remote from the third dynode 106 are more accelerated, and a transit time of the secondary electrons passing through this area is shortened.

An electron orbit 72 of those of the secondary electrons emitted from the first dynode 104 to the second dynode 105, which have a shorter transit time, and an electron orbit 73 of those of the same, which have a longer transit time under the operational conditions of TABLE 1 are shown. The electrons having a shorter transit time (the electron orbit 72) take 780 psecs to reach the second dynode 105, and the electrons having a longer transit time (the electron orbit 73) take 880 psecs to get to the second dynode 105. The difference between these transit times is 100 psecs, and the distribution of these transit times is as shown in FIG. 5C. The transit time spread is much improved in comparison with that of the prior art shown in FIG. 5A. FIG. 4C shows an embodiment of the photomultiplier according to this invention having improved transit time spreads.

The photomultiplier according to this embodiment further includes an orbit correcting electrode 62 between the first dynode 104 and the second dynode 105. The orbit correcting electrode 62 is for suppressing the influence by the third dynode 106 which has a higher potential than the first and the second dynodes 104, 105, and has a lower potential than the third dynode 106. In this embodiment, the orbit correcting electrode 62 and the first dynode 104 are connected by a lead wire 83 to set both at the same potential.

As seen in FIG. 4C, because of the orbit correcting electrode 62, the equipotential line E is suppressed from bulging toward the first dynode 104 in this territory. As a result, the electrons which are accelerated by the third dynode 106 in FIG. 1 are not accelerated, and the electron orbits are converged. The difference between the transit times is further more decreased.

In a simulation, the electrons having a shorter transit time (the electron orbit 74) take 840 psecs to arrive at the second dynode 105, and the electrons having a longer transit time (the electron orbit 75) take 890 psecs. The difference between these transit times is 50 psecs, and a distribution of the transit times is as shown in Fig. 5D. A transit time spread is more decreased in comparison with that of the prior art of Fig. 5A. Owing to the convergence of the electrode orbits, spreads which take place after the second dynode 105 can be suppressed.

Thus, in embodiments of this invention, transit time spreads of the secondary electrons can be much suppressed. As a result, transient response characteristics of photodetection can be much improved. Since a time resolving power depends on a transient response characteristic, the photomultiplier according to this invention enables high time-resolved spectrometry.

This invention is not limited to the above-described embodiments and covers various modifications and variations within the scope of the appended claims.

For example, the above-described embodiments have been explained by means of head-on type, but this invention is applicable to the side-on type. In the above-described embodiments, electrons are cascade-multiplied by ten stages of dynodes, but a number of the stages may be larger or smaller than the above.

Claims

1. A photomultiplier for receiving incident light on a photocathode (103) and cascade-multiplying electrons emitted from the photocathode by the secondary electronic effect of a plurality of dynodes (104 to 113), whereby the incident light is detected, the photomultiplier comprising:

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an electrode (60) positioned so as to act on secondary electrons emitted from a first dynode (104) to a second dynode (105), and positioned adjacent a third dynode (106) of a subsequent stage to said first and second dynodes;
characterised in that
said electrode (60) is a decelerating electrode connected to a source of a lower potential than that of said third dynode (106), so as to reduce the spread in the transit times of the electrons between said first (104) and second (105) dynodes.

2. A photomultiplier as claimed in claim 1, wherein the decelerating electrode (60) is connected to a source of the same potential as said second dynode (105).

3. A photomultiplier for receiving incident light on a photocathode (103) and cascade-multiplying electrons emitted from the photocathode by the secondary electronic effect of a plurality of dynodes (104 to 113), whereby the incident light is detected, the photomultiplier comprising:

an electrode (60) positioned so as to act on secondary electrons emitted from a first dynode (104) to a second dynode (105), and positioned adjacent a third dynode (106) of a subsequent stage to said first and second dynodes;
characterised in that
said electrode (60) is a decelerating electrode electrically connected to said second dynode (105), for reducing the spread in the transit times of the electrode between said first (104) and second (105) dynodes.

4. A photomultiplier as claimed in any preceding claim, further comprising an accelerating electrode (61) connected to a source of a higher potential than said second dynode (105) so as to accelerate those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which have a lower speed.

5. A photomultiplier as claimed in claim 4, wherein the accelerating electrode (61) is connected to a source of the same potential as a fourth dynode (107) of a stage subsequent to said third dynode (106).

6. A photomultiplier as claimed in claim 5, wherein the accelerating electrode (61) is electrically connected to said fourth dynode (107).

7. A photomultiplier as claimed in any one of claims 1 to 4, further comprising an accelerating electrode (61) connected to a fourth dynode (107) of a subsequent stage to that of said third dynode (106), for accelerating those of the secondary electrons emitted from the first dynode (104) to the second-stage dynode (105) which have a lower speed.

8. A photomultiplier as claimed in any one of claims 4 to 7, wherein the accelerating electrode (61) is disposed near electron paths (73) of those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which pass remote from said third dynode (106), and is disposed near said second dynode (105).

9. A photomultiplier as claimed in any one of claims 1 to 8, further comprising a path correcting electrode (62) connected to a source of a lower potential than said third dynode (106) so as to correct electron paths (74) of those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which pass near said third dynode (106), so as to reduce further the spread in the transit times of the electrons between said first and second dynodes.

10. A photomultiplier as claimed in claim 9, wherein the path correcting electrode (62) has the same potential as said first dynode (104).

11. A photomultiplier according to claim 9 or claim 10, wherein the path correcting electrode (62) is electrically connected to said first dynode (104).

12. A photomultiplier as claimed in any one of claims 1 to 8, further comprising a path correcting electrode (62) electrically connected to said first dynode (104), for correcting electron paths (74) of those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which pass near said third dynode (106), so as to reduce further the spread in the transit times of the electrons between said first and second dynodes.

13. A photomultiplier as claimed in any one of claims 9 to 12, wherein the path correcting electrode (62) is disposed

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nearer said first dynode (104) than the decelerating electrode (60), and near electron paths (74) passing near the decelerating electrode.

14. A photomultiplier as claimed in any preceding claim, wherein said first dynode (104) is a first-stage dynode for receiving electrons emitted from the photocathode (103);

said second dynode (105) is a second-stage dynode disposed opposite to the first-stage dynode (104) for receiving secondary electrons emitted from the first-stage dynode; and
said third dynode (106) is a third-stage dynode disposed opposite to the second-stage dynode (105) for receiving secondary electrons emitted from the second-stage dynode.

15. A photomultiplier as claimed in claim 14 when dependent on claim 6 or claim 7, wherein said fourth dynode (107) is a fourth-stage dynode, for receiving secondary electrons emitted from the third-stage dynode (106).

16. A method of operating a photomultiplier for receiving incident light on a photocathode (103) and cascade-multiplying electrons emitted from the photocathode by the secondary electronic effect of a plurality of dynodes (104 to 113), whereby the incident light is detected, the photomultiplier comprising:

an electrode (60) positioned so as to act on secondary electrons emitted from a first dynode (104) to a second dynode (105), and positioned adjacent a third dynode (106) of a subsequent stage to said first and second dynodes;
said method being characterised by applying to said electrode (60) a lower potential than that of said third dynode (106), so as to reduce the spread in the transit times of the electrons between said first (104) and second (105) dynodes.

17. A method as claimed in claim 16, wherein the same potential as that of said second dynode (105) is applied to the decelerating electrode (60).

18. A method as claimed in claim 16 or 17, further comprising applying to an accelerating electrode (61) a higher potential than that of said second dynode (105) so as to accelerate those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which have a lower speed.

19. A method as claimed in claim 18, wherein the same potential is applied to the accelerating electrode (61) as to a fourth dynode (107) of a stage subsequent to said third dynode (106).

20. A method as claimed in any one of claims 16 to 19, further comprising applying to a path correcting electrode (62) a lower potential than that of said third dynode (106) so as to correct electron paths (74) of those of the secondary electrons emitted from said first dynode (104) to said second dynode (105) which pass near said third dynode (106), so as to reduce further the spread in the transit times of the electrons between said first and second dynodes.

21. A method as claimed in claim 20, wherein the same potential is applied to the path correcting electrode (62) as to said first dynode (104).

Patentansprüche

1. Photovervielfacher zum Empfangen von einfallendem Licht auf einer Photokathode (103) und zum Kaskaden-Multiplizieren von von der Photokathode emittierten Elektronen durch die sekundärelektronische Wirkung einer Vielzahl von Dynoden (104 bis 113), wodurch das einfallende Licht erfaßt wird, mit:

einer Elektrode (60), die positioniert ist, um auf von einer ersten Dynode (104) zu einer zweiten Dynode (105) emittierte Sekundärelektronen einzuwirken, und benachbart einer dritten Dynode (106) einer der ersten und zweiten Dynode nachfolgenden Stufe positioniert ist;
dadurch gekennzeichnet, daß
die Elektrode (60) eine Verzögerungselektrode ist, die mit einer Quelle eines niedrigeren Potentials als das der dritten Dynode (106) verbunden ist, um die Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten (104) und zweiten (105) Dynode zu verringern.

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2. Photovervielfacher nach Anspruch 1,

dadurch gekennzeichnet, daß
die Verzögerungselektrode (60) mit einer Quelle des gleichen Potentials wie die zweite Dynode (105) verbunden ist.

3. Photovervielfacher zum Empfangen von einfallendem Licht auf einer Photokathode (103) und zum Kaskaden-Multiplizieren von von der Photokathode emittierten Elektronen durch die sekundärelektronische Wirkung einer Vielzahl von Dynoden (104 bis 113), wodurch das einfallende Licht erfaßt wird, mit:

einer Elektrode (60), die positioniert ist, um auf von einer ersten Dynode (104) zu einer zweiten Dynode (105) emittierte Sekundärelektronen einzuwirken, und benachbart einer dritten Dynode (106) einer der ersten und zweiten Dynode nachfolgenden Stufe positioniert ist;
dadurch gekennzeichnet, daß
die Elektrode (60) eine mit der zweiten Dynode (105) elektrisch verbundene Verzögerungselektrode zum Verringern der Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten (104) und zweiten (105) Dynode ist.

4. Photovervielfacher nach einem der vorangehenden Ansprüche,

gekennzeichnet durch
eine Beschleunigungselektrode (61), die mit einer Quelle eines höheren Potentials als die zweite Dynode (105) verbunden ist, um diejenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die eine niedrigere Geschwindigkeit haben, zu beschleunigen.

5. Photovervielfacher nach Anspruch 4,

dadurch gekennzeichnet, daß
die Beschleunigungselektrode (61) mit einer Quelle des gleichen Potentials wie eine vierte Dynode (107) einer der dritten Dynode (106) nachfolgenden Stufe verbunden ist.

6. Photovervielfacher nach Anspruch 5,

dadurch gekennzeichnet, daß
die Beschleunigungselektrode (61) mit der vierten Dynode (107) elektrisch verbunden ist.

7. Photovervielfacher nach einem der Ansprüche 1 bis 4,

gekennzeichnet durch
eine Beschleunigungselektrode (61), die mit einer vierten Dynode (107) einer der dritten Dynode (106) nachfolgenden Stufe verbunden ist zum Beschleunigen derjenigen der von der ersten Dynode (104) zur Dynode (105) der zweiten Stufe emittierten Sekundärelektronen, die eine niedrigere Geschwindigkeit besitzen.

8. Photovervielfacher nach einem der Ansprüche 4 bis 7,

dadurch gekennzeichnet, daß
die Beschleunigungselektrode (61) nahe von Elektronenpfaden (73) derjenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die entfernt von der Dynode (106) vorbeilaufen, angeordnet ist und nahe der zweiten Dynode (105) angeordnet ist.

9. Photovervielfacher nach einem der Ansprüche 1 bis 8,

gekennzeichnet durch
eine Pfadkorrekturelektrode (62), die mit einer Quelle eines niedrigeren Potentials als die dritte Dynode (106) verbunden ist, um Elektronenpfade (74) von denjenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die nahe der dritten Dynode (106) vorbeilaufen, zu korrigieren, um die Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten und zweiten Dynode weiter zu verringern.

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10. Photovervielfacher nach Anspruch 9,

dadurch gekennzeichnet, daß
die Pfadkorrekturelektrode (62) das gleiche Potential wie die erste Dynode (104) besitzt.

11. Photovervielfacher nach Anspruch 9 oder 10,

dadurch gekennzeichnet, daß
die Pfadkorrekturelektrode (62) mit der ersten Dynode (104) elektrisch verbunden ist.

12. Photovervielfacher nach einem der Ansprüche 1 bis 8,

gekennzeichnet durch
eine Pfadkorrekturelektrode (62), die mit der ersten Dynode (104) elektrisch verbunden ist, zum Korrigieren von Elektronenpfaden (74) derjenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die nahe der dritten Dynode (106) vorbeilaufen, um die Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten und zweiten Dynode weiter zu verringern.

13. Photovervielfacher nach einem der Ansprüche 9 bis 12,

dadurch gekennzeichnet, daß
die Pfadkorrekturelektrode (62) näher bei der ersten Dynode (104) angeordnet ist als eine Verzögerungselektrode (60), und nahe Elektronenpfade (74) nahe der Verzögerungselektrode vorbeilaufen.

14. Photovervielfacher nach einem der vorangehenden Ansprüche,

dadurch gekennzeichnet, daß
die erste Dynode (104) eine Dynode einer ersten Stufe zum Empfangen von von der Photokathode (103) emittierten Elektronen ist;
die zweite Dynode (105) eine Dynode einer zweiten Stufe, die entgegengesetzt zur Dynode (104) der ersten Stufe angeordnet ist, zum Empfangen von von der Dynode der ersten Stufe emittierten Sekundärelektronen ist; und
die dritte Dynode (106) eine Dynode einer dritten Stufe, die entgegengesetzt zur Dynode (105) der zweiten Stufe angeordnet ist, zum Empfangen von von der Dynode der zweiten Stufe emittierten Sekundärelektronen ist.

15. Photovervielfacher nach Anspruch 14, wenn abhängig von Anspruch 6 oder 7,

dadurch gekennzeichnet, daß
die vierte Dynode (107) eine Dynode einer vierten Stufe zum Empfangen von von der Dynode (106) der dritten Stufe emittierten Sekundärelektronen ist.

16. Verfahren zum Betreiben eines Photovervielfachers zum Empfangen von einfallendem Licht auf einer Photokathode (103) und zum Kaskaden-Multiplizieren von von der Photokathode emittierten Elektronen durch die sekundärelektronische Wirkung einer Vielzahl von Dynoden (104 bis 113), wodurch das einfallende Licht erfaßt wird, wobei der Photovervielfacher umfaßt:

eine Elektrode (60), die positioniert ist, um auf von einer ersten Dynode (104) zu einer zweiten Dynode (105) emittierte Sekundärelektronen einzuwirken, und benachbart einer dritten Dynode (106) einer der ersten und zweiten Dynode nachfolgenden Stufe positioniert ist;
wobei das Verfahren gekennzeichnet ist durch
Anlegen eines niedrigeren Potentials als das der dritten Dynode (106) an die Elektrode (60), um die Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten (104) und zweiten (105) Dynode zu verringern.

17. Verfahren nach Anspruch 16,

dadurch gekennzeichnet, daß
das gleiche Potential wie das der zweiten Dynode (105) an die Verzögerungselektrode (60) angelegt wird.

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18. Verfahren nach Anspruch 16 oder 17,

gekennzeichnet durch
Anlegen eines höheren Potentials als das der zweiten Dynode (105) an eine Beschleunigungselektrode (61), um diejenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die eine niedrigere Geschwindigkeit besitzen, zu beschleunigen.

19. Verfahren nach Anspruch 18,

dadurch gekennzeichnet, daß
das gleiche Potential an die Beschleunigungselektrode (61) angelegt wird wie an eine vierte Dynode (107) einer der dritten Dynode (106) nachfolgenden Stufe.

20. Verfahren nach einem der Ansprüche 16 bis 19,

gekennzeichnet durch
Anlegen eines niedrigeren Potentials als das der dritten Dynode (106) an eine Pfadkorrekturelektrode (62), um Elektronenpfade (74) von denjenigen der von der ersten Dynode (104) zur zweiten Dynode (105) emittierten Sekundärelektronen, die nahe der dritten Dynode (106) vorbeilaufen, zu korrigieren, um die Spanne bei den Durchgangszeiten der Elektronen zwischen der ersten und zweiten Dynode weiter zu verringern.

21. Verfahren nach Anspruch 20,

dadurch gekennzeichnet, daß
das gleiche Potential an die Pfadkorrekturelektrode (62) angelegt wird wie an die erste Dynode (104).

Revendications

1. Photomultiplicateur pour la réception d'une lumière incidente sur une photocathode (103) et pour la multiplication en cascade d'électrons émis par la photocathode par effet électronique secondaire d'une pluralité de dynodes (104 à 113), la lumière incidente étant ainsi détectée, photomultiplicateur comprenant :

   - une électrode (60) placée de façon à agir sur des électrons secondaires émis par une première dynode (104) vers une seconde dynode (105), et placée adjacente à une troisième dynode (106) d'un étage suivant vers lesdites première et seconde dynodes;

   photomultiplicateur caractérisé en ce que ladite électrode (60) est une électrode de décélération connectée à une source d'un plus faible potentiel que celui de ladite troisième dynode (106) de façon à réduire la dispersion dans les temps de transition des électrons entre ladite première (104) et ladite seconde (105) dynodes.

2. Photomultiplicateur selon la revendication 1, dans lequel l'électrode de décélaration (60) est raccordée à une source de même potentiel que ladite seconde dynode (105).

3. Photomultiplicateur pour la réception d'une lumière incidente sur une photocathode (103) et pour la multiplication en cascade d'électrons émis par la photocathode par effet électronique secondaire d'une pluralité de dynodes (104 à 113), la lumière incidente étant ainsi détectée, photomultiplicateur comprenant :

   - une électrode (60) placée de façon à agir sur des électrons secondaires émis par une première dynode (104) vers une seconde dynode (105), et placée adjacente à une troisième dynode (106) d'un étage suivant vers lesdites première et seconde dynodes;

   photomultiplicateur caractérisé en ce que ladite électrode (60) est une électrode de décélération électriquement raccordée à ladite seconde dynode (105) pour la réduction de la dispersion dans les temps de transition de l'électrode entre ladite première (104) et ladite seconde (105) dynodes.

4. Photomultiplicateur selon l'une quelconque des revendications précédentes, comprenant, de plus, une électrode d'accélération (61) raccordée à une source d'un plus haut potentiel que ladite seconde dynode (105) de façon à

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accélérer les électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) qui présentent une vitesse plus faible.

5. Photomultiplicateur selon la revendication 4, dans lequel l'électrode d'accélération (61) est raccordée à une source du même potentiel qu'une quatrième dynode (107) d'un étage suivant ladite troisième dynode (106).

6. Photomultiplicateur selon la revendication 5, dans lequel l'électrode d'accélération (61) est électriquement raccordée à ladite quatrième dynode (107).

7. Photomultiplicateur selon l'une quelconque des revendications 1 à 4, comprenant, de plus, une électrode d'accélération (61) raccordée à une quatrième dynode (107) d'un étage suivant ladite troisième dynode (106) pour l'accélération des électrons secondaires émis de la première dynode (104) vers la dynode de second étage (105) possédant une plus faible vitesse.

8. Photomultiplicateur selon l'une quelconque des revendications 4 à 7, dans lequel l'électrode d'accélération (61) est placée près des circuits d' électrons (73) des électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) passant à l'écart de ladite troisième dynode (106), et est placée près de ladite seconde dynode (105).

9. Photomultiplicateur selon l'une quelconque des revendications 1 à 8, comprenant, de plus, une électrode de correction de circuit (62) raccordée à une source de plus bas potentiel que ladite troisième dynode (106) de façon à corriger les trajets électroniques (74) des électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) passant près de ladite troisième dynode (106) de façon à réduire, de plus, la dispersion dans les temps de transition des électrons entre lesdites première et seconde dynodes.

10. Photomultiplicateur selon la revendication 9, dans lequel l'électrode de correction de circuit (62) possède le même potentiel que ladite première dynode (104).

11. Photomultiplicateur selon la revendication 9 ou 10, dans lequel l'électrode de correction de circuit (62) est électriquement raccordée à ladite première dynode (104).

12. Photomultiplicateur selon l' une quelconque des revendications 1 à 8, comprenant, de plus, une électrode de correction de circuit (62) électriquement raccordée à ladite première dynode (104) pour corriger les trajets électroniques (74) des électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) passant près de ladite troisième dynode (106) de façon à réduire, de plus, la dispersion dans les temps de transition des électrons entre lesdites première et seconde dynodes.

13. Photomultiplicateur selon l'une quelconque des revendications 9 à 12, dans lequel l'électrode de correction de circuit (62) est placée plus proche de ladite première dynode (104) que l'électrode de décélération (60), et proche des circuits électroniques (74) passant près de l'électrode de décélération.

14. Photomultiplicateur selon l'une quelconque des revendications précédentes, dans lequel ladite première dynode (104) est une dynode de premier étage pour la réception des électrons émis par la photocathode (103);

ladite seconde dynode (105) est une dynode de second étage placée en opposition à la dynode de premier étage (104) pour la réception des électrons secondaires émis par la dynode de premier étage; et
ladite troisième dynode (106) est une dynode de troisième étage placée en opposition à la dynode de second étage (105) pour la réception des électrons secondaires émis par la dynode de second étage.

15. Photomultiplicateur selon la revendication 14, lorsque dépendante de la revendication 6 ou 7, dans lequel ladite quatrième dynode (107) est une dynode de quatrième étage pour la réception des électrons secondaires émis par la dynode de troisième étage (106).

16. Procédé de mise en oeuvre d'un photomultiplicateur pour la réception d'une lumière incidente sur une photocathode (103) et pour la multiplication en cascade des électrons émis par la photocathode par l'effet électronique secondaire d'une pluralité de dynodes (104 à 113), la lumière incidente étant ainsi détectée, le photomultiplicateur comprenant :

- une électrode (60) placée de façon à agir sur des électrons secondaires émis par une première dynode (104)

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vers une seconde dynode (105), et adjacente à une troisième dynode (106) d'un étage suivant lesdites première et seconde dynodes;

procédé caractérisé par l'applicateur à ladite électrode (60) d'un plus faible potentiel que celui de ladite troisième dynode (106) de façon à réduire la dispersion dans les temps de transition des électrodes entre lesdites première (104) et seconde (105) dynodes.

17. Procédé selon la revendication 16, selon lequel le même potentiel que celui de ladite seconde dynode (105) est appliqué à l'électrode de décélération (60).

18. Procédé selon la revendication 16 ou 17, comprenant, de plus, l'application à une électrode d'accélération (61) d'un plus haut potentiel que celui de ladite seconde dynode (105) de façon à accélérer les électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) ayant une plus faible vitesse.

19. Procédé selon la revendication 18, selon lequel le même potentiel est appliqué à l'électrode d'accélération (61) et à une quatrième dynode (107) d'un étage suivant ladite troisième dynode (106).

20. Procédé selon l'une quelconque des revendications 16 à 19, comprenant, de plus, l'application à une électrode de correction de circuit (62) d'un plus faible potentiel que celui de ladite troisième dynode (106) de façon à corriger les trajets électroniques (74) des électrons secondaires émis par ladite première dynode (104) vers ladite seconde dynode (105) passant près de ladite troisième dynode (106) de façon à réduire, de plus, la dispersion dans les temps de transition des électrons entre lesdites première et seconde dynodes.

21. Procédé selon la revendication 20, selon lequel le même potentiel est appliqué à l'électrode de correction de circuit (62) et à ladite première dynode (104).

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Fig. 1

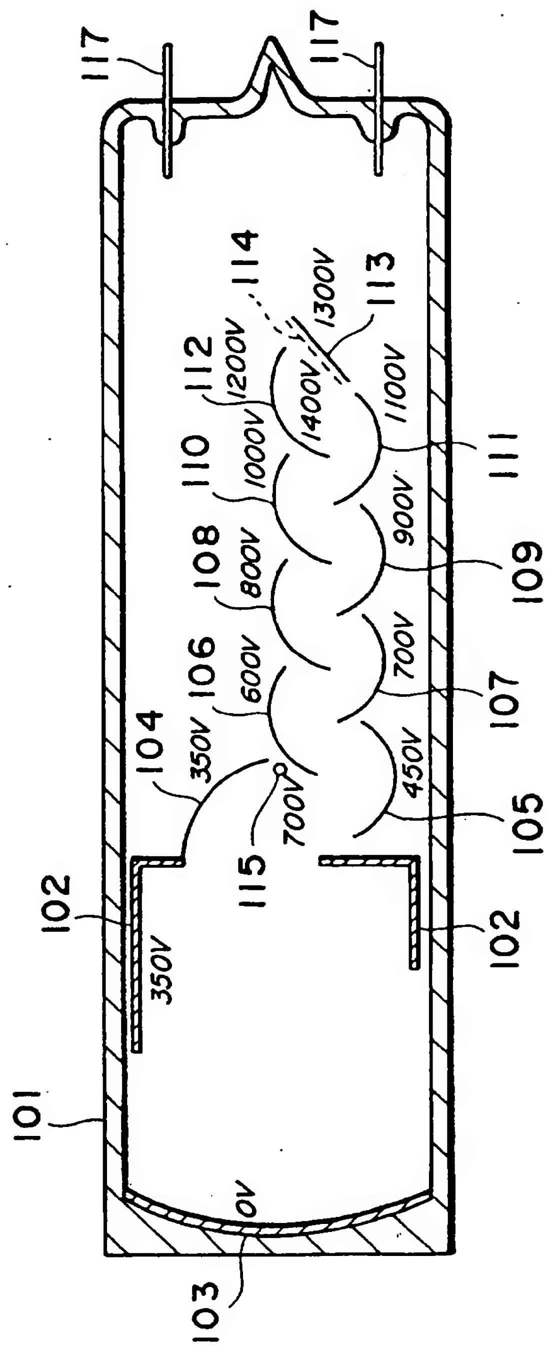

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Fig. 2

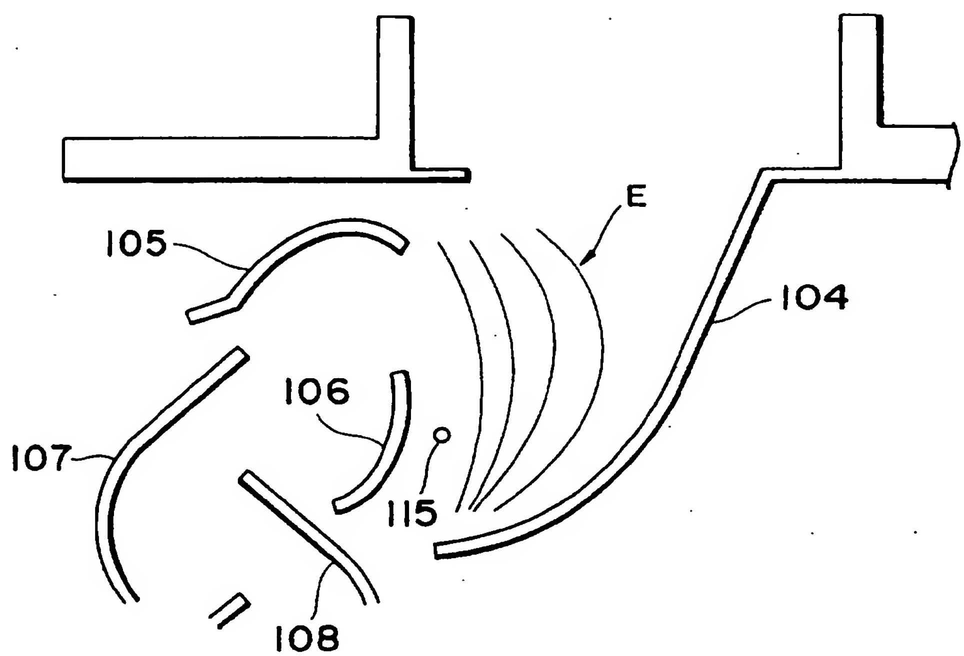

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Fig. 3

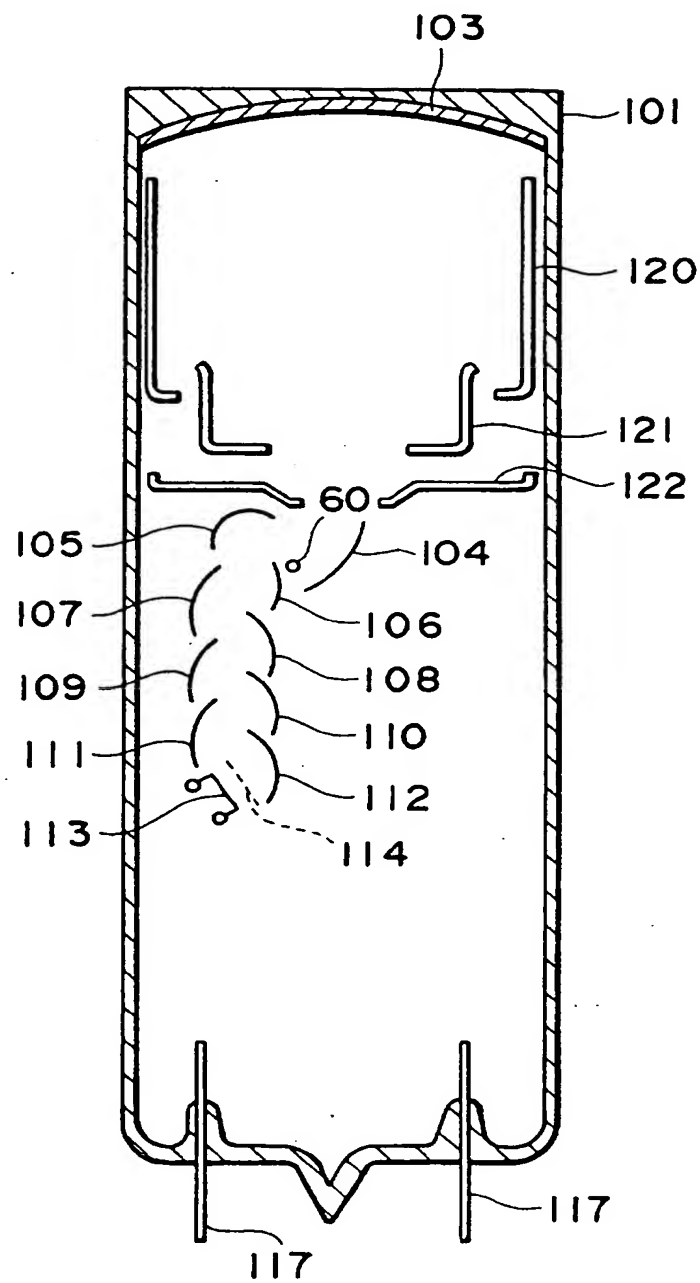

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Fig.4A

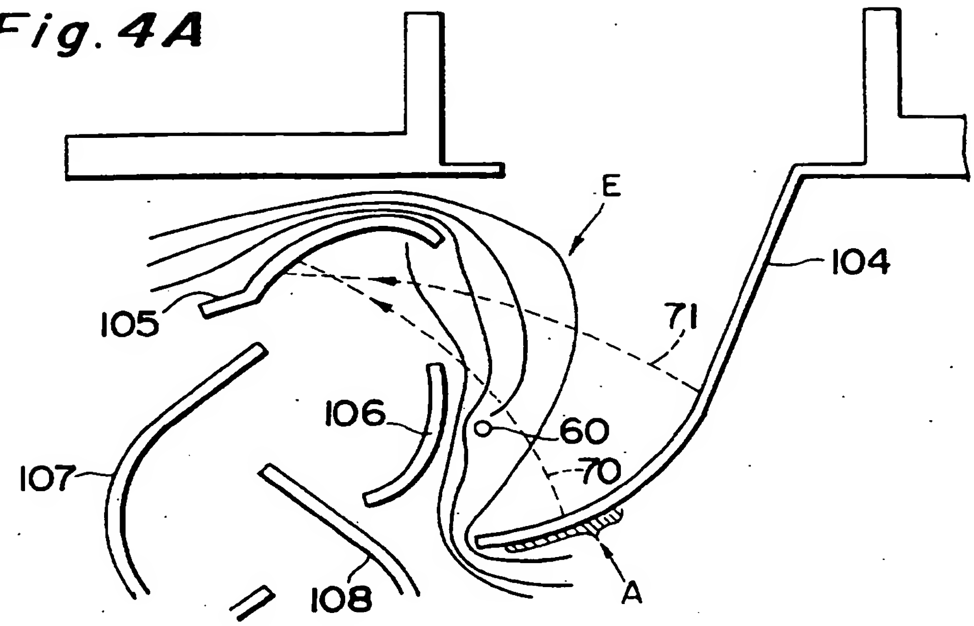

Fig.4B

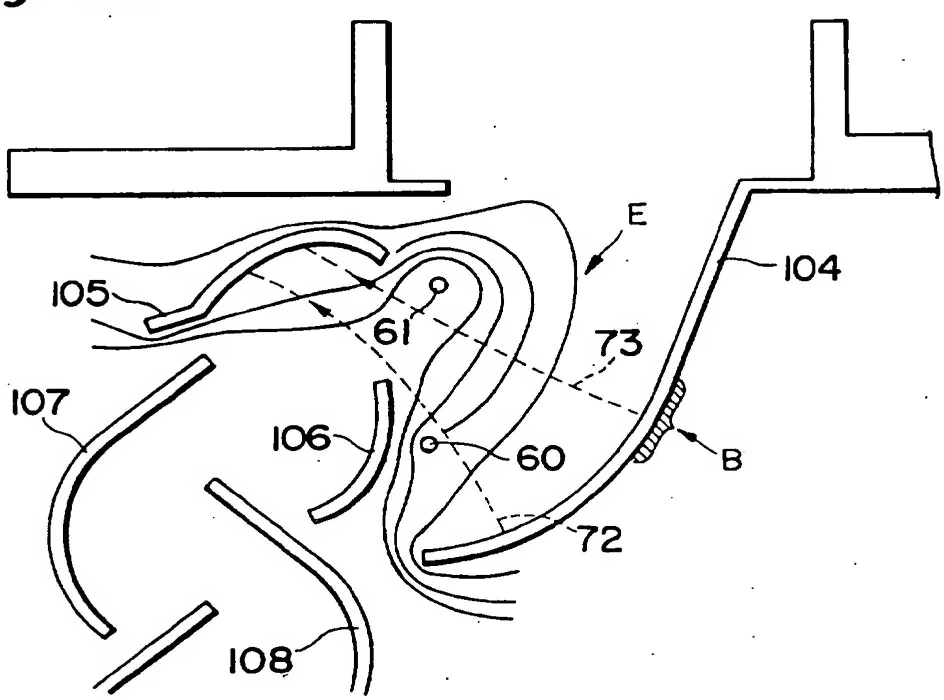

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Fig.4C

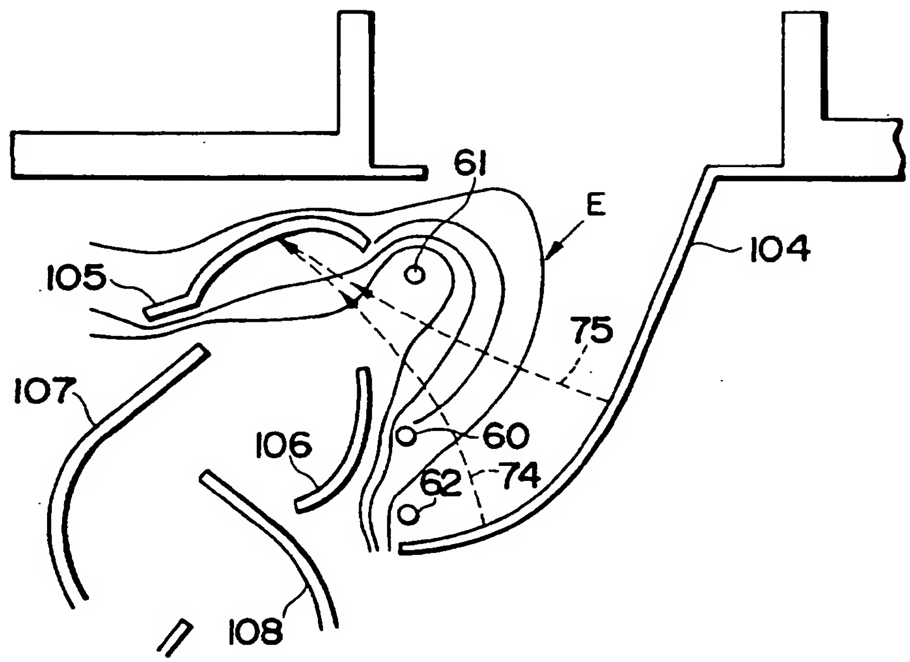

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Fig. 5A

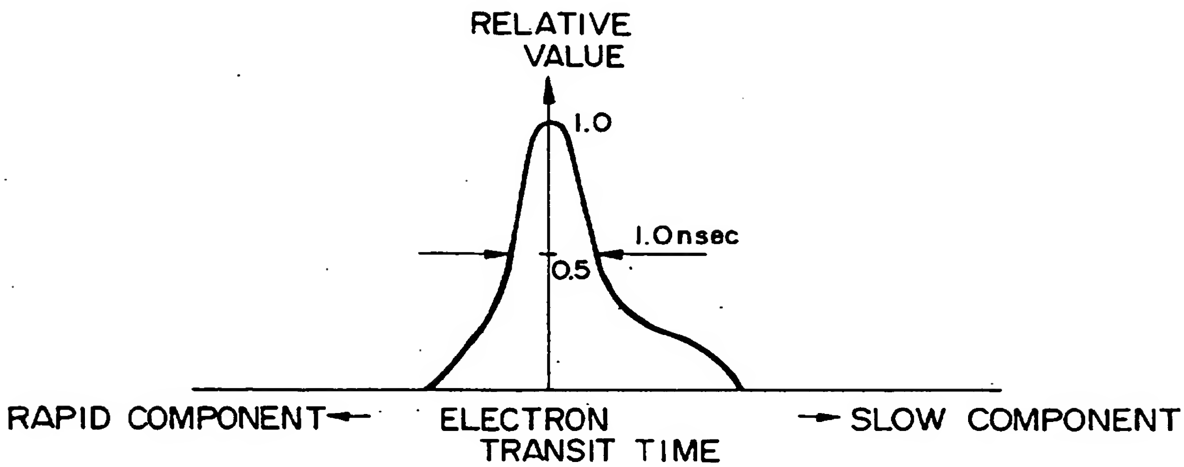

Fig. 5B

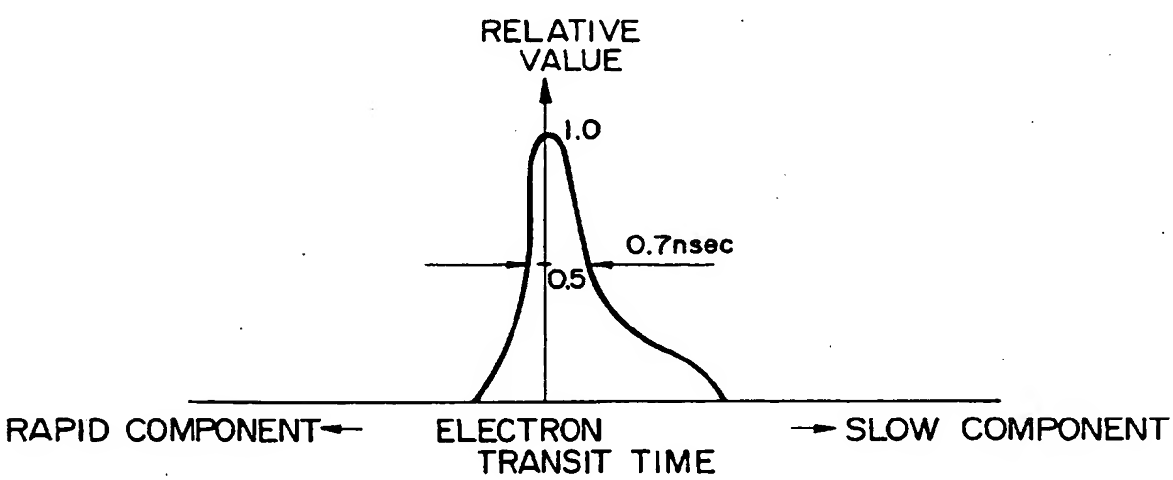

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Fig. 5C

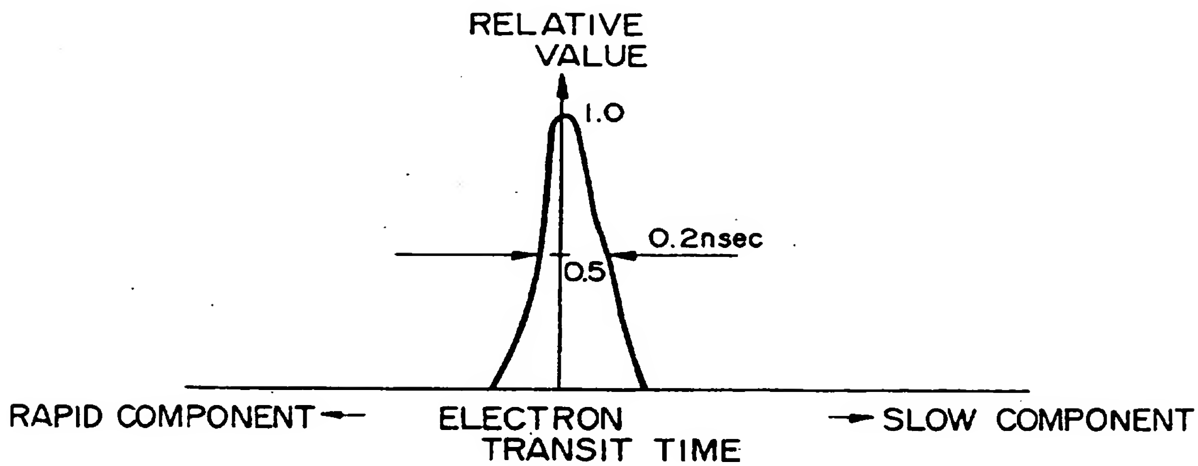
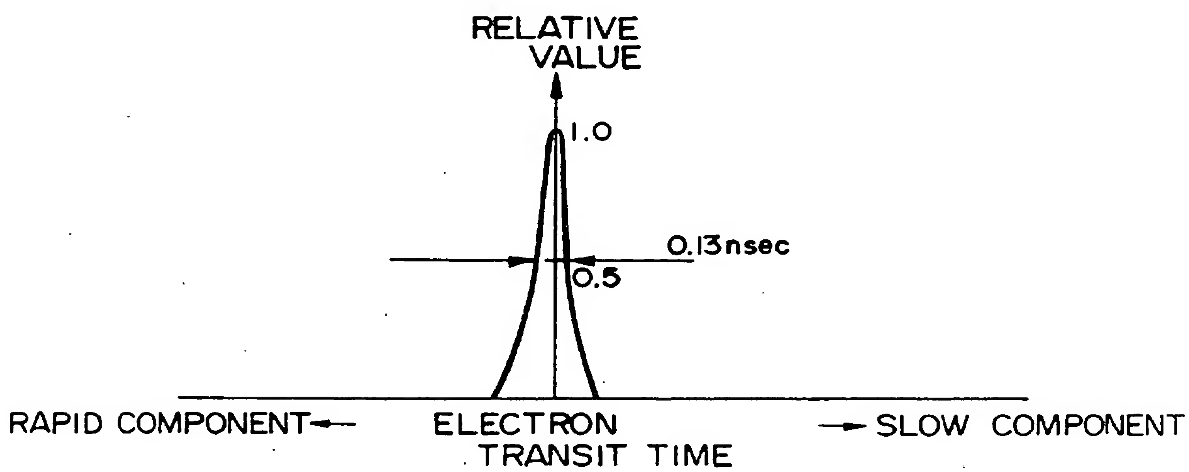


Fig. 5D



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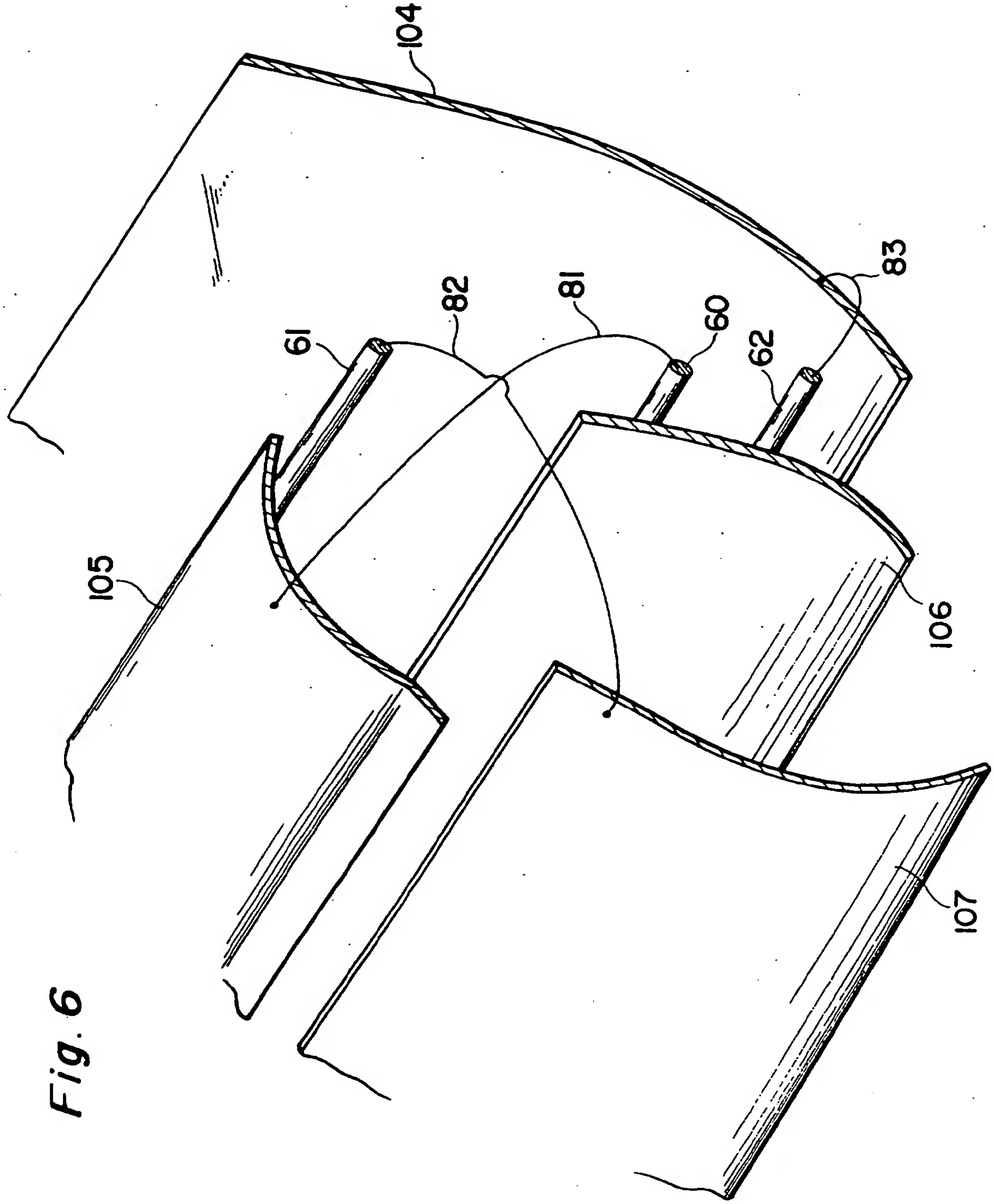

Fig. 6

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